

Influence of Fossil-fuel Power Plant Emissions on the Surface PM_{2.5} in the Seoul Metropolitan Area, South Korea

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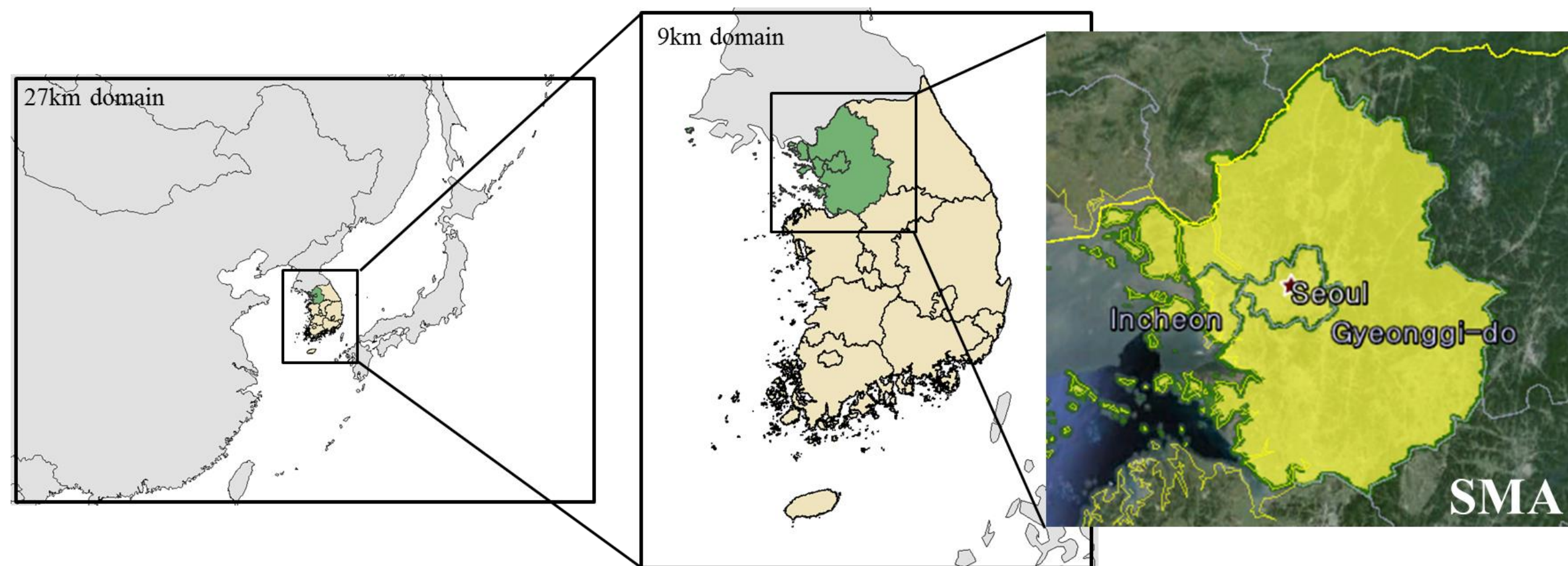
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Introduction

- ✓ Many large fossil-fuel power plants are located near the Seoul Metropolitan Area (SMA), the highest population density and largest population area in South Korea.
- ✓ Since NO_x and SO₂ emissions from fossil-fuel power plants have significant impacts on the regional PM_{2.5} air quality, the impact of emissions from additional fossil fuel based electricity generation on the air quality in the SMA needs to be understood and quantified.
- ✓ Therefore, we estimate the contribution of fossil-fuel power plants on PM_{2.5} concentration in SMA to support air quality planning with respect to future electricity demand changes.

Methodology

◆ Modeling Domains



◆ Modeling Period

January, April, July, and October 2010 to represent winter, spring, summer, and fall

◆ Model Configuration

We utilize the WRF - SMOKE - CMAQ framework.

CMAQ		WRF	
Version	Version 4.7.1	Version	Version 3.4.1
Chemical Mechanism	SAPRC 99	Micro Physics	WSM6(Hong and Lim, 2006)
Aerosol Module	AERO5	Cumulus Scheme	Kaio-Fritsch(Kain 2004)
Boundary Condition	Default profile for the 27km domain	Long wave radiation	RRTM(Mlawer et al, 1997)
Advection Scheme	YAMO	Short wave	Dudhia Scheme
Horizontal Diffusion	Multiscale	PBL Scheme	YSU(Hong et al, 2006)
Vertical Diffusion	Eddy	LSM Scheme	NOAH(Chen and Dudhia 2001)
Cloud Scheme	RADM		

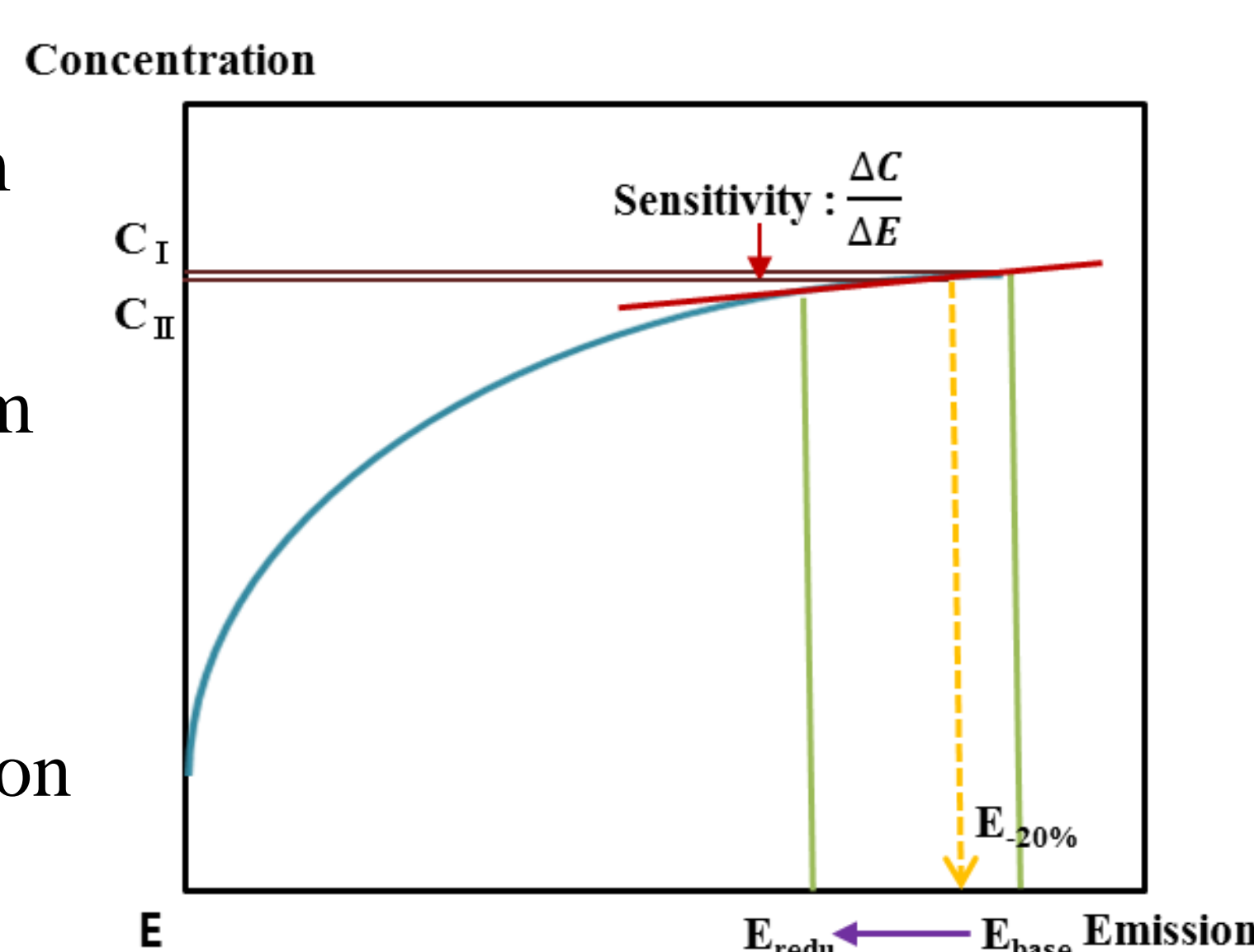
◆ Analysis of Contributions

Contributions from power plant are estimated using the BFM (Brute Force Method).

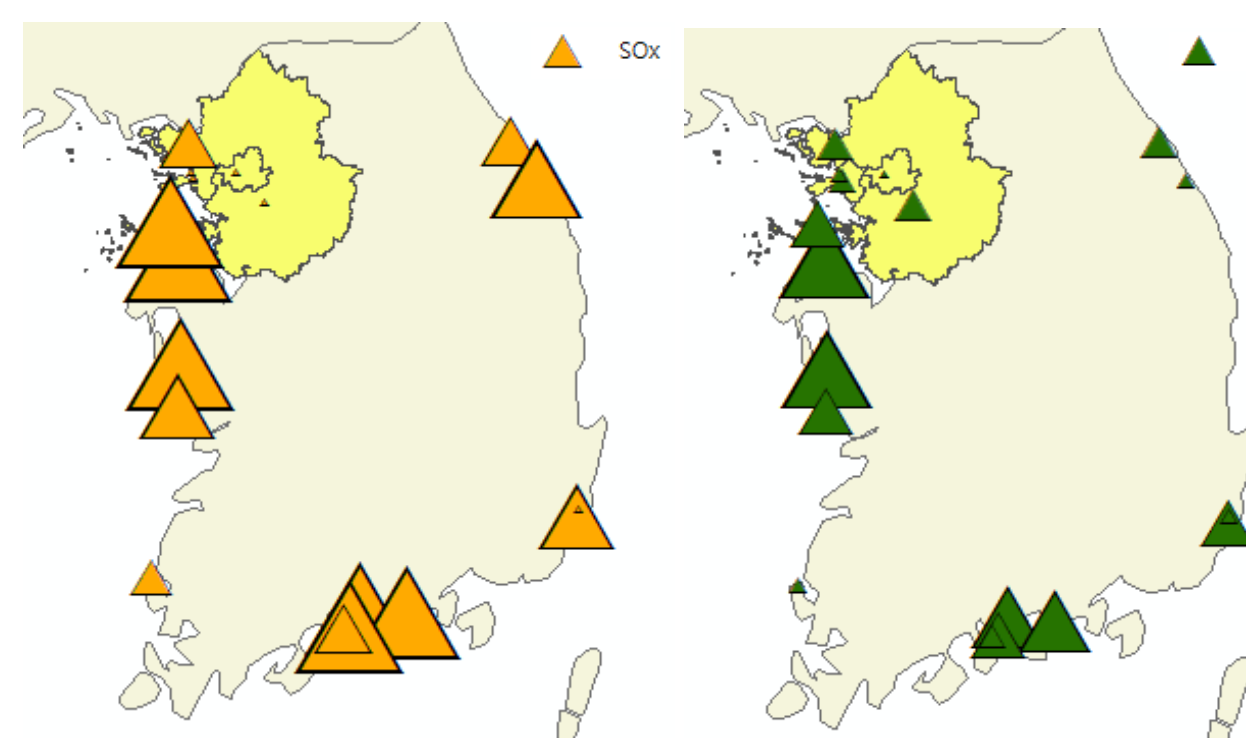
- SMA PM_{2.5} Concentration from base case run, C_I
- SMA PM_{2.5} Concentration from 20 % reduction case, C_{II}
- Sensitivity of SMA PM_{2.5} concentration to 20 % Emission Reduction of Power Plants

$$\Delta C = (C_I - C_{II})$$

- Contribution of power plants = 5 X ΔC



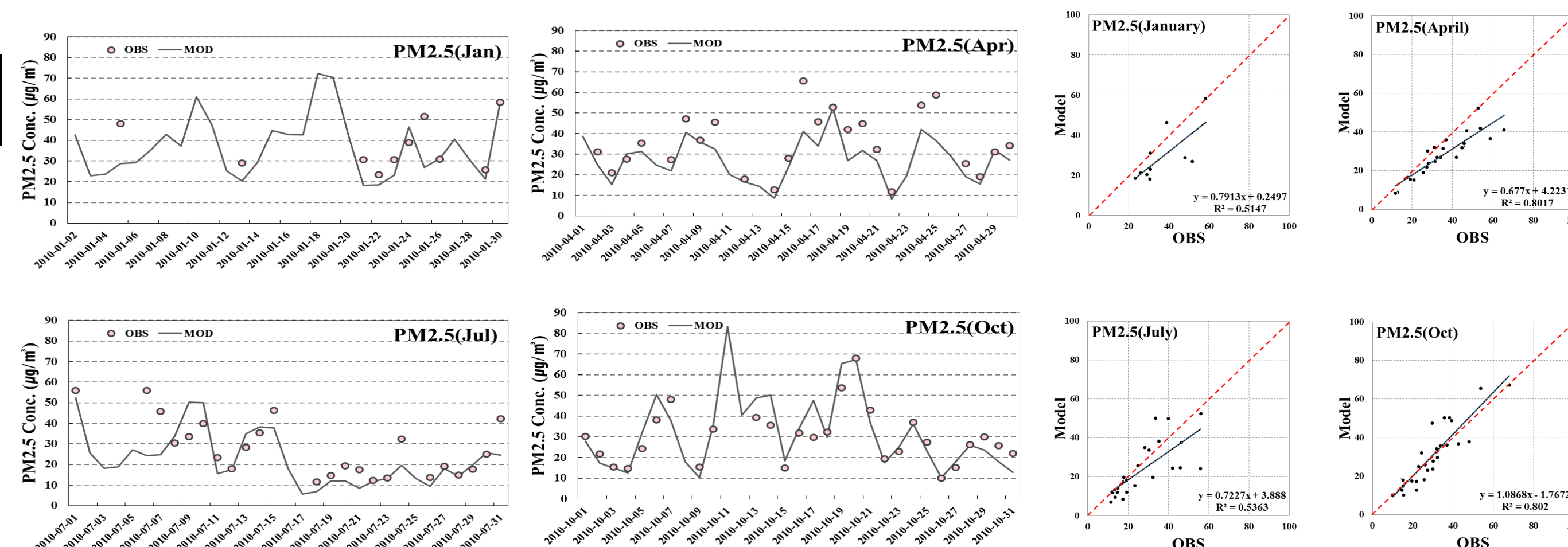
◆ Large Fossil-fuel Power Plant in South Korea



- ✓ NO_x and SO_x emissions from fossil-fuel power plants is 91,227 tons and 52,372 tons in 2010.
- ✓ These emissions account for 9 % of the total NO_x emissions and 13 % of SO_x emission in South Korea.

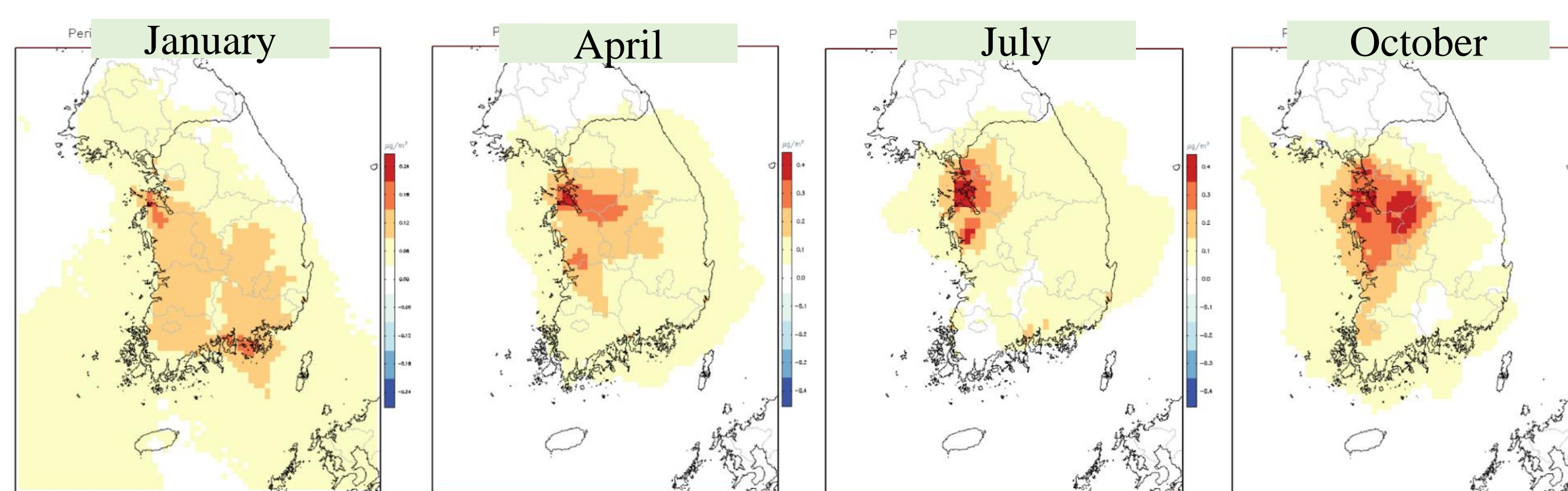
Results and Discussion

◆ Model Performance Evaluation



- ✓ The model showed the best performance in October (R²=0.802) and the worst performance in January (R²=0.515). However, there were many days with missing observations in January. Therefore, the estimated model performance statistics for January may not be used critically.

◆ Monthly Average PM_{2.5} Contribution

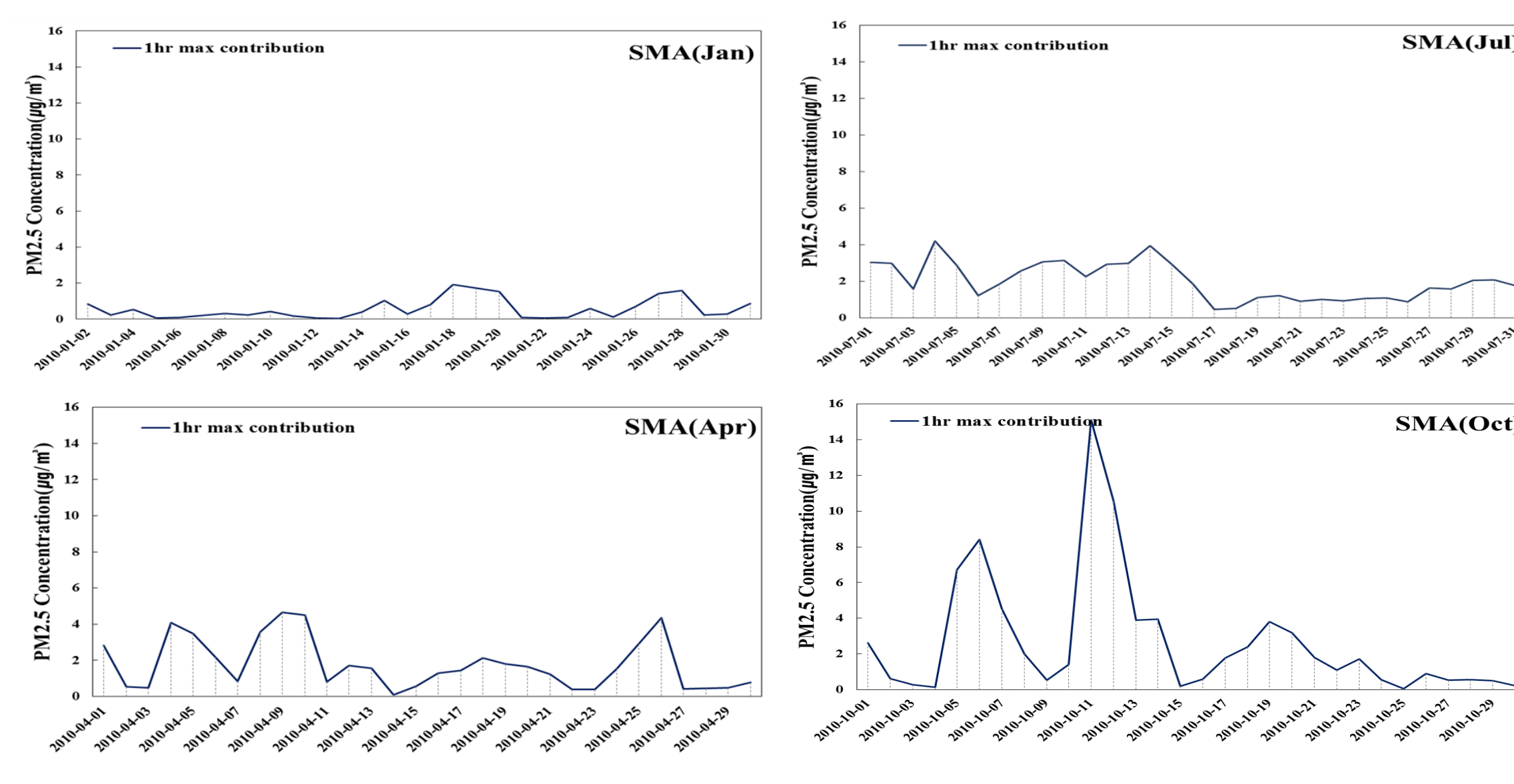


Month	January	April	July	October
PM2.5 Conc.	30.14	21.5	14.85	23.84
Contribution Conc.	0.29	0.92	1.12	1.22

(Unit : μg/m³)

- ✓ The largest PM_{2.5} contribution by power plants occurs in October while the smallest contribution happens in January.

◆ Hourly PM_{2.5} Concentrations and Maximum Contribution



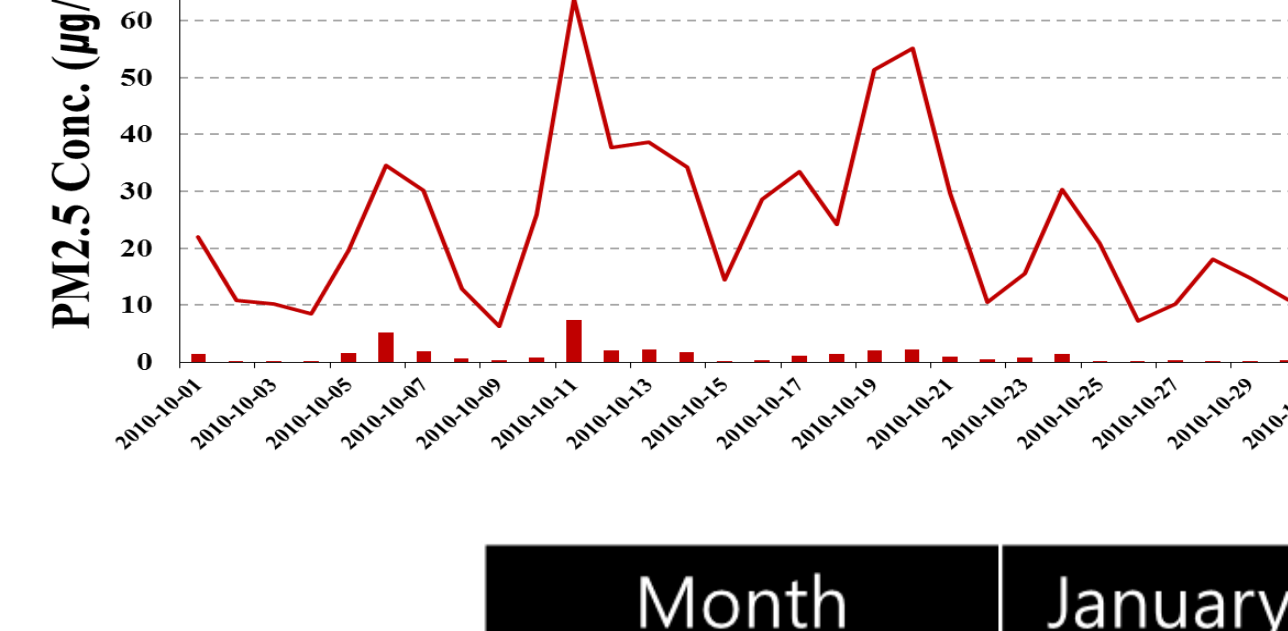
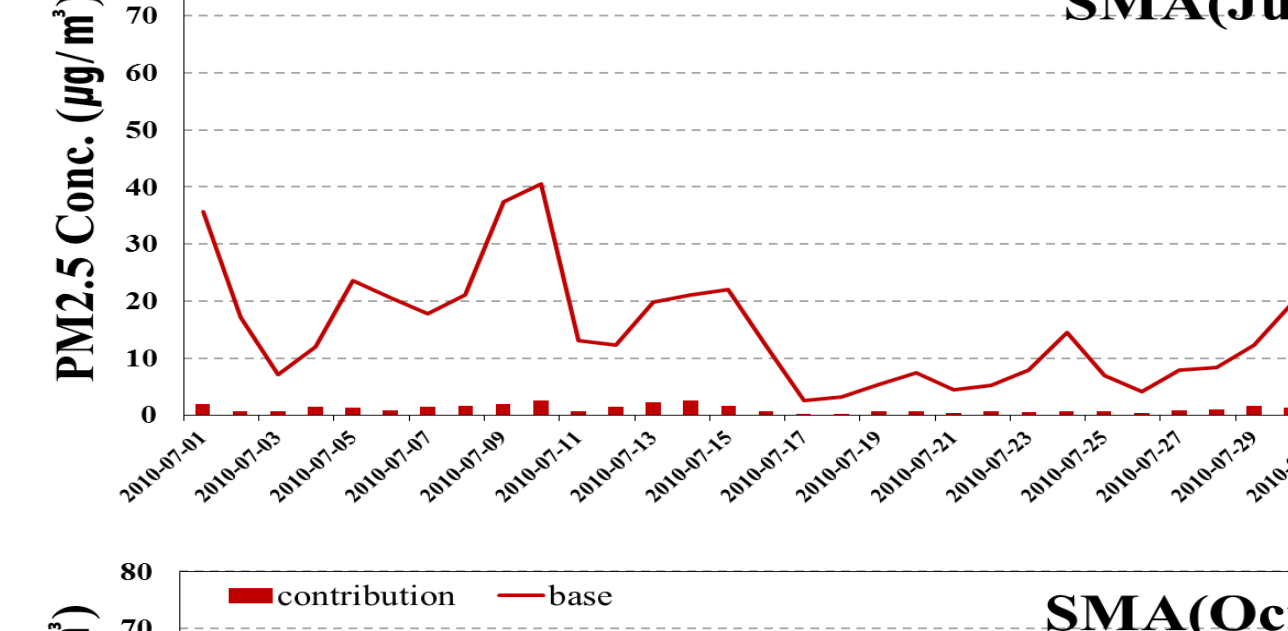
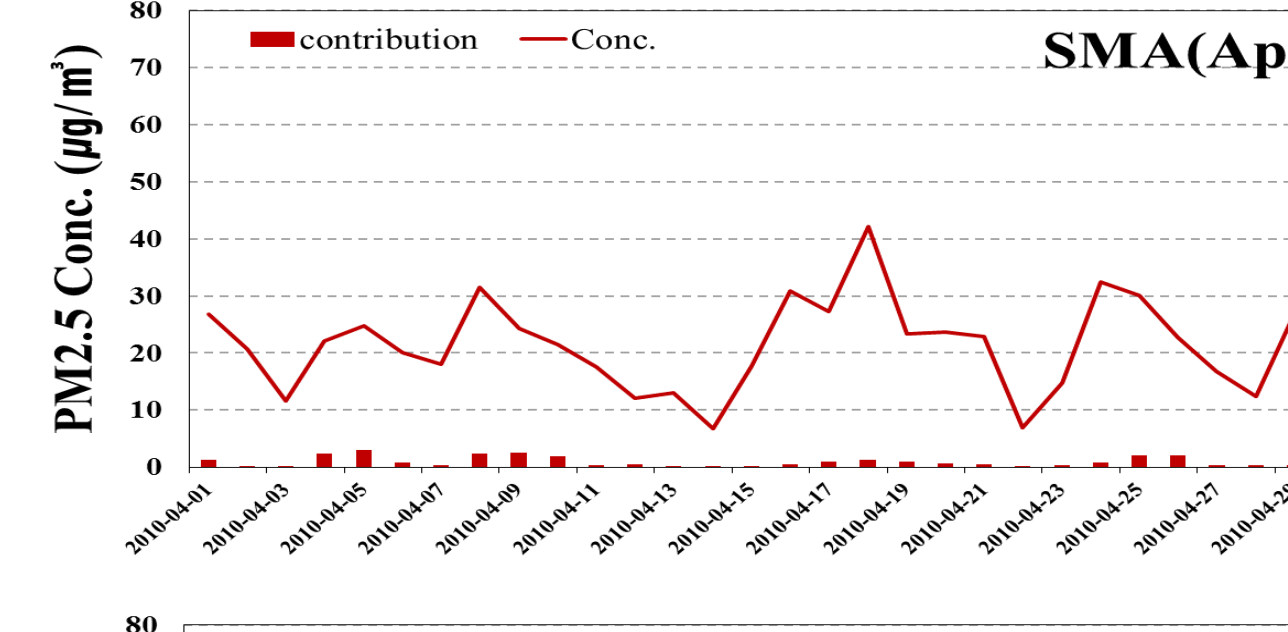
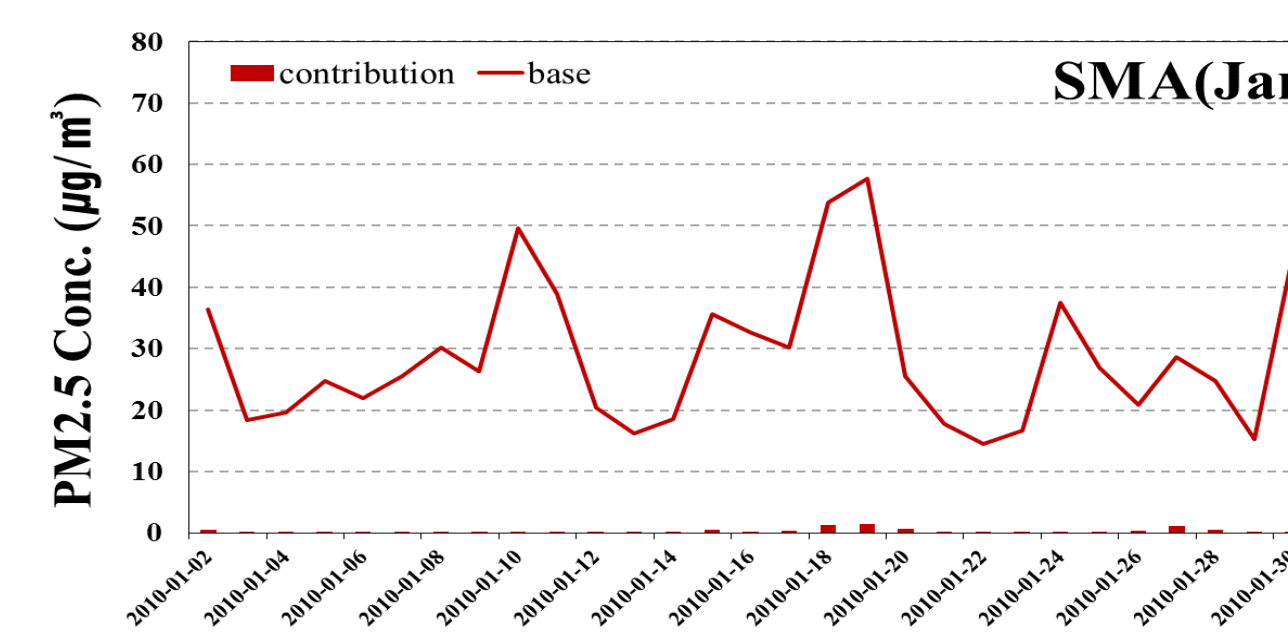
Month	January	April	July	October
PM2.5 Conc.	59.2	44.8	7.5	66.7
1hr max Contribution Conc.	1.9	4.7	4.2	15.1

(Unit : μg/m³)

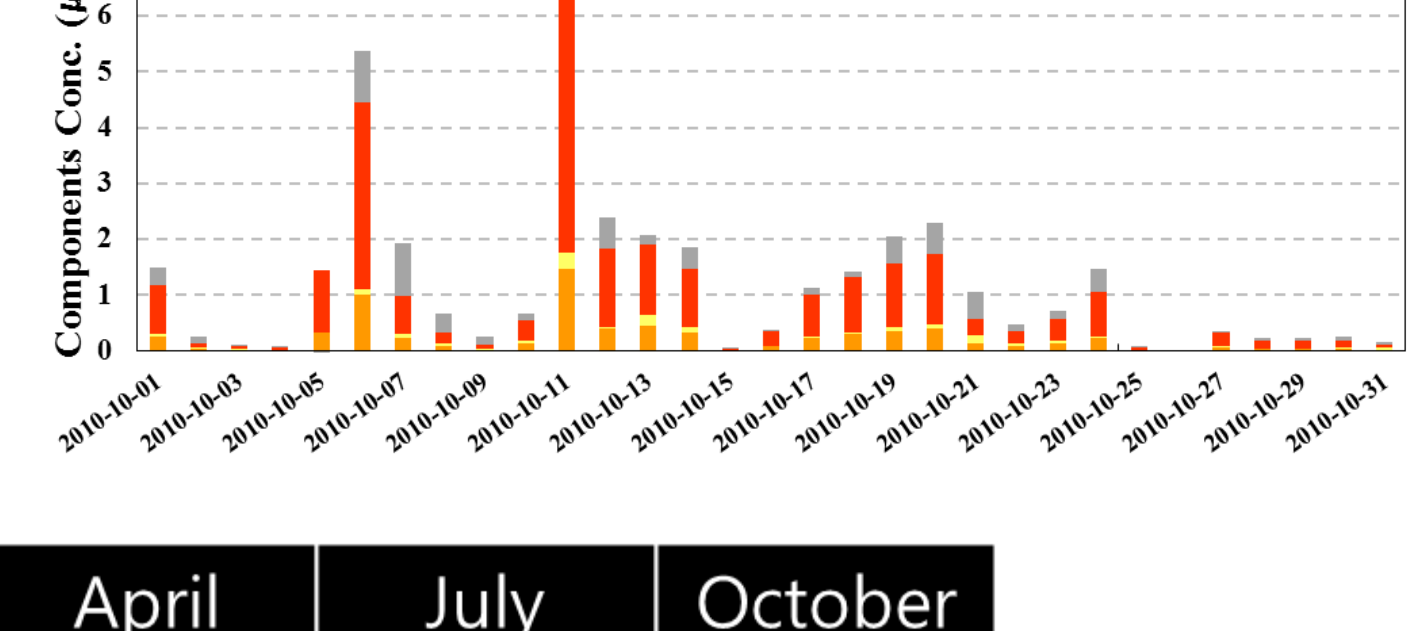
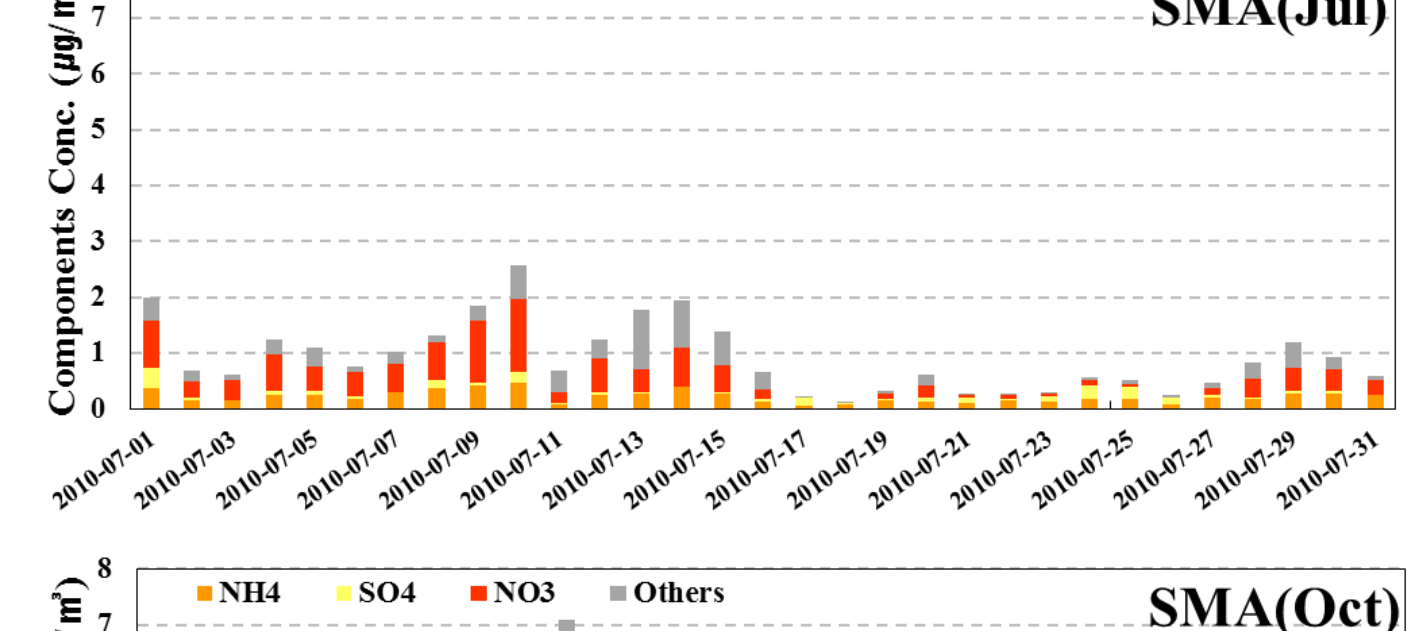
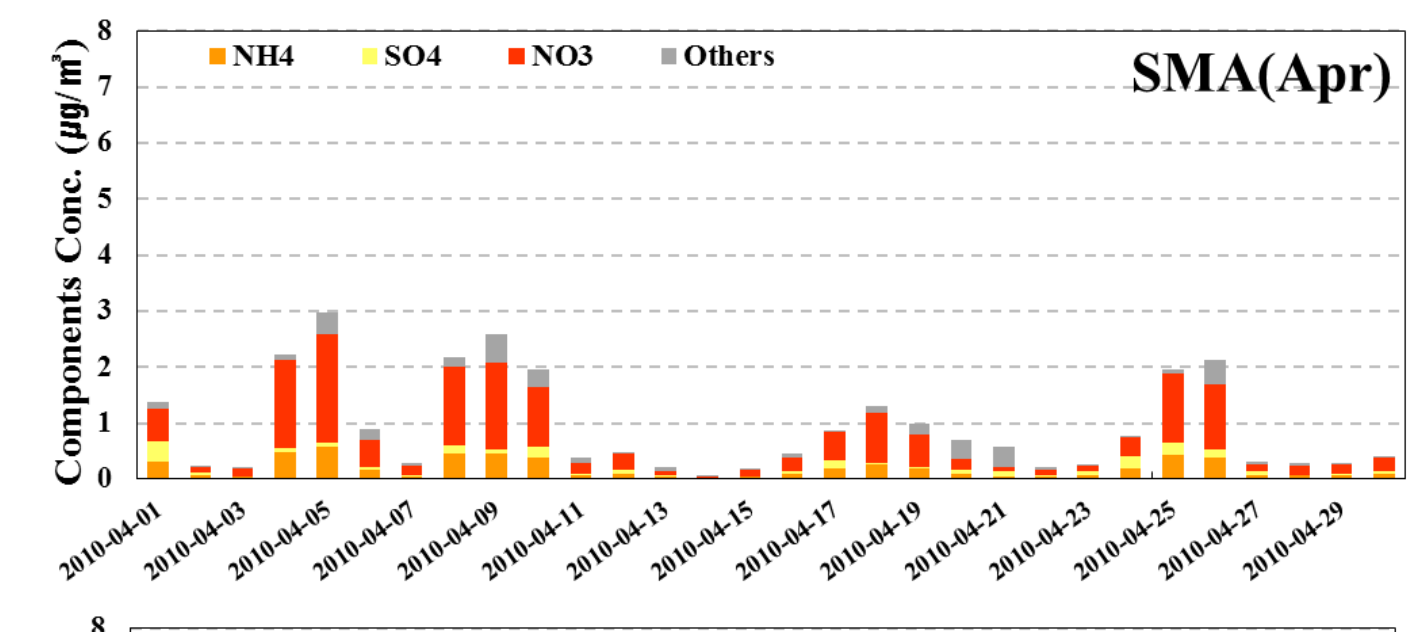
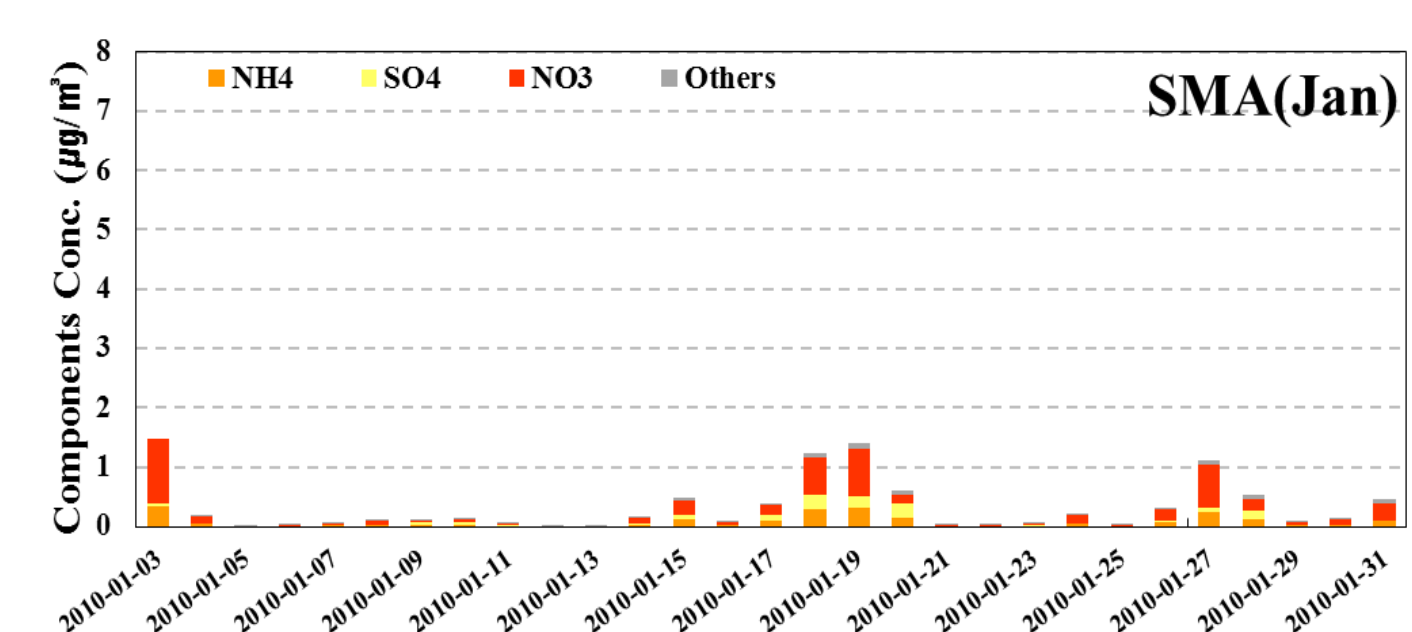
- ✓ In January, power plant emissions showed an overall smallest contribution and while relatively larger contribution in October.

◆ Daily Contribution of PM_{2.5} and its major constituents

- PM_{2.5} Conc. & Contribution



- PM_{2.5} Components Contribution



Month	January	April	July	October
PM2.5 Conc.	57.7	24.7	40.86	63.3
Daily average max Contribution Conc.	1.4	3.0	2.6	7.1

(Unit : μg/m³)

- ✓ Simulated monthly PM_{2.5} concentration in January was its highest among four months selected.
- ✓ On October 11, PM_{2.5} concentration was 63.3 μg/m³ which is over the Korean air quality standard for 24-hr PM_{2.5}, 50μg/m³. For the day, Power plant contribution is 7.1 μg/m³ which is 14% of the standard.
- ✓ In summer, among the components of PM_{2.5}, relative portion of sulfate and ammonium to the total PM_{2.5} is increased although the contribution of nitrate is the most significant in general.

Conclusion and Implication

- ✓ Contribution of domestic fossil fuel power plant emissions to the surface PM_{2.5} in SMA, South Korea where over 20 million people live was estimated.
- ✓ The average monthly PM_{2.5} contribution in the SMA was 0.29μg/m³ in January and 1.22μg/m³ in October. The estimated annual average PM_{2.5} contribution is 0.9 μg/m³.
- ✓ According to “2nd Metropolitan Air Quality Control Master Plan”, South Korean government plans to improve regional annual PM_{2.5} concentrations from 27μg/m³ in 2010 to 20μg/m³ in 2024.
- ✓ Air quality managers can utilize the results of this study to design anticipated power plant control requirements to keep up with additional energy supply plans such as ‘6th Electricity Supply Plan’.
- ✓ Seasonal variations of PM_{2.5} components may need to be accounted in the future air quality management.

Acknowledgement

- ✓ This work was supported by Korea Ministry of Environment and Korea Environment Institute.